Modeling of the Atmospheric Circulation in the Santa Barbara Channel

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LONG-TERM GOALS

The long term goal is to better understand and predict the physics of small to mesoscale circulations in the coastal atmosphere using a combination of observations and model simulations.

OBJECTIVES

The objective of this project is to determine how local, coastal wind fields in the Santa Barbara Channel (SBC) region are affected by slowly varying synoptic weather conditions and diurnal heating. Hindcast simulations have been performed for a two-week period in April that encompassed both strong synoptic forcing representative of winter conditions, and circulations that are driven by local heating, which are more typical in summer. Wind stress from these simulations will be provided to investigators examining the role of local winds in forcing coastal ocean circulations.

APPROACH

Simulations were performed using the Advanced Regional Prediction System (ARPS) mesoscale model developed at the University of Oklahoma (Xue et al. 1995). ARPS is a nonhydrostatic atmospheric mesoscale model that uses a terrain following coordinate system with both parameterized and explicit cloud physics. Two levels of nesting were employed in the simulations using a horizontal grid size of 60 x 60 and grid spacing of 12 km and 4 km, respectively. A stretched 32 level vertical grid was applied with grid spacing starting at 20 m for the finest resolution at the surface expanding to 450 m for the top grid levels. Initialization and boundary forcing for the model were prescribed using the National Center for Environmental Prediction (NCEP) 40 km Eta model analysis, which is available in 3 hour increments and archived at the National Center for Atmospheric Research. Hindcasts were performed over 12-hr periods with a 3 hour spin up prior to the beginning of the hindcast.

WORK COMPLETED

Hindcasts from April 7-14th, 1998 are nearing completion and will be interpolated to a uniform latitude/longitude grid for distribution to ocean modeling efforts. We have started to examine the role of terrain and local heating in determining the strength and location of wind stress shear over the SBC.

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RESULTS

Simulations of the SBC circulation during April show a broad range of flow conditions that were largely determined by synoptic weather events. This report focuses on one particular case on April 8, 1998, when the wind direction and speed varied significantly across the SBC. A plot of the 10 m winds and sea level pressure from this case are shown in Figure 1 along with a plot of the surface topography.

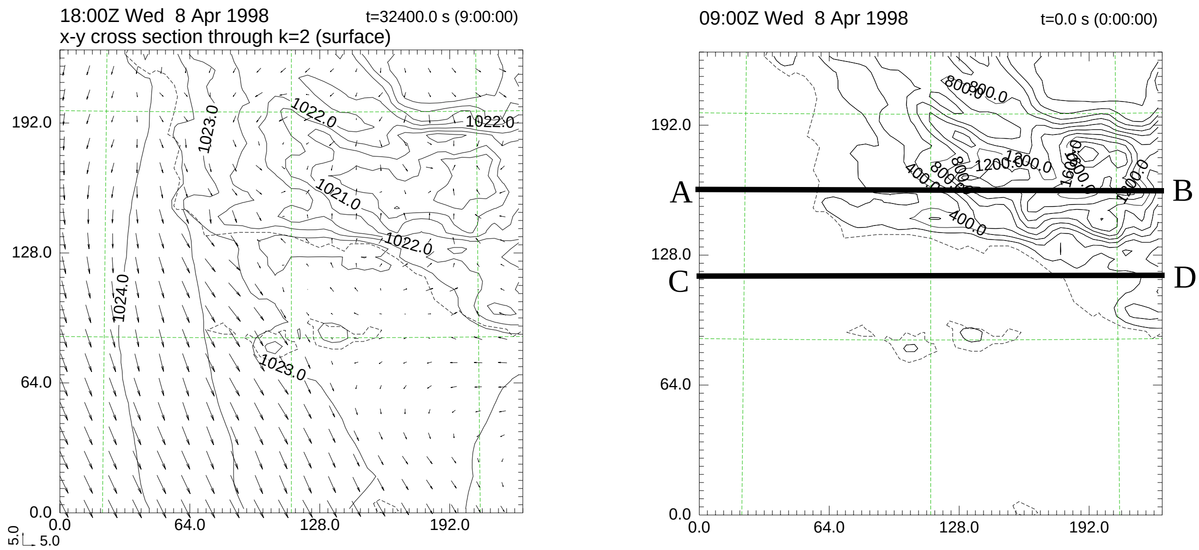

Figure 1. Plots of the 10-m wind vectors and sea level pressure taken from 18Z on April 8, 1998 (left) and model topography (right). Pressure contours are in kPa.

Synoptic conditions at this time placed a high pressure system off of the California coast creating a surface pressure gradient aligned in a north-south direction as shown by the sea level pressure in Fig. 1. The low-level wind field associated with this pressure gradient is nearly geostrophic, except in the region near Pt. Conception where the flow reacts to the changing coastal boundary. North of Pt. Conception, the flow speed is reduced as the marine boundary layer interacts with the coastal topography. South of the point, the topography is effectively removed, which forces a low pressure system in the lee of the Santa Ynez mountains. The effect of the low pressure is most noticeable at the western end of the SBC where the flow direction crosses the isobars. Further south, the winds and pressure gradient fan out as the flow comes into balance with the new coastline location. Winds in the eastern portion of the SBC are in a distinctly different regime from the open ocean flow. Here, local heating of the terrain causes weak upslope flow indicated by the onshore wind vectors. Comparison of these results with wind observations taken from buoys in the western SBC and station observations from Santa Barbara show good qualitative agreement.

The vertical structure of the meridional wind is more clearly shown through cross section plots from A-B and C-D from Fig. 1. In the northern section (A-B), the alongshore flow has a minimum centered near the top of the boundary layer at ~50 km zonal distance, with a strong reduction in the southward flow as one moves over the coastline. This coastal northerly jet appears to be separated from the surface layer as shown by the strong reduction in the speed as the ocean surface is approached. The southern section (C-D) also shows the northerly jet in approximately the same location as the northern section, however, the near surface velocity at this location is stronger indicating more vertical exchange of momentum.

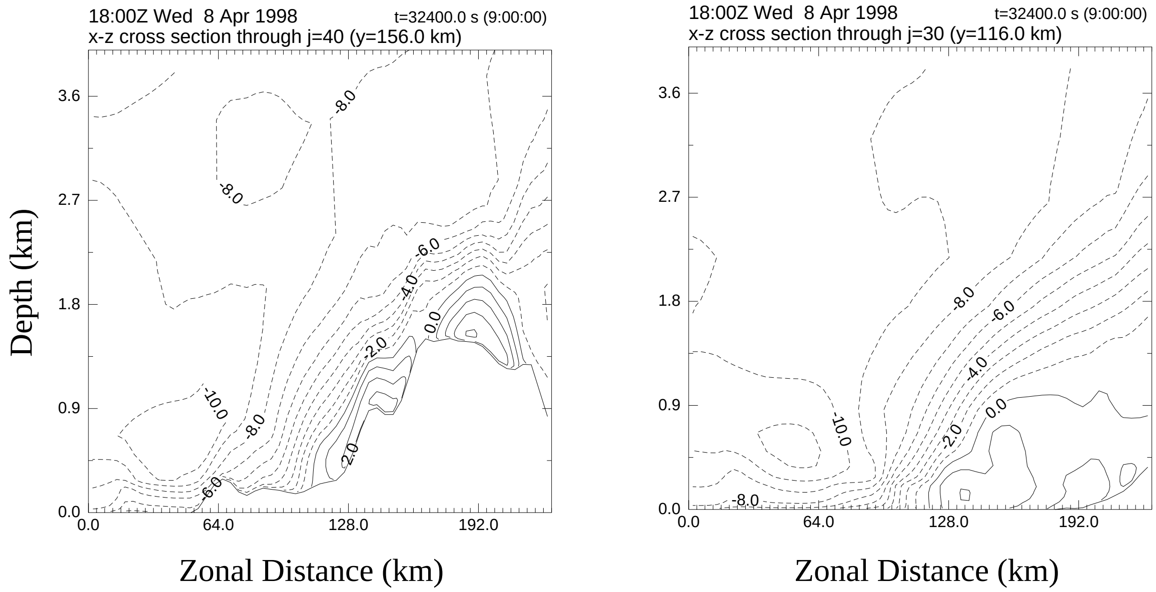

Figure 2. Zonal cross sections of the meridional velocity (v) as a function of height (km). Cross section locations are labeled A-B and C-D, respectively, in Fig. 1.

Overall, the meridional flow at both sections is quite similar, even though the northern section has significant terrain. This close comparison demonstrates how the SBC region is sheltered by the abrupt change in coastline at Pt. Conception. For this particular case, the flow is unable as it passes around the point, but instead continues southward and becomes part of the larger scale circulation known as the "Catalina Eddy" (Thompson et al. 1997). Other cases have been examined that have greater intrusion of the northerly flow into the SBC, with some cases having strong curvature at Pt. Conception and westerly winds across the channel. An example of this is shown in Figure 3 taken from later in the day on April 8th. At this time, a front moved through the area causing the sea level pressure gradient to move inland.

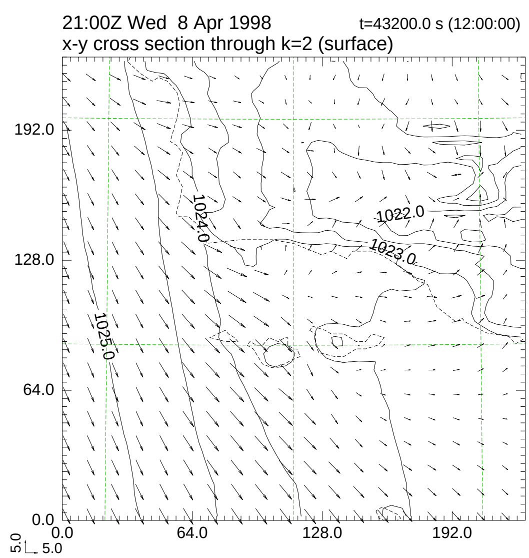

Figure 3. Plots of the 10-m wind vectors and sea level pressure at 21Z on April 8, 1998.

Winds in the SBC respond by turning to a more westerly direction with the strong horizontal shear displaced to the center of the channel.

IMPACT/APPLICATIONS

The April hindcasts provide a detailed wind stress field for use as surface forcing in coastal ocean models. To ensure that these winds have the most accuracy, wind observations from the Scripps Center for Coastal Studies will be incorporated using a data assimilation routine that is part of the ARPS modeling package (as soon as the data are made available).

The April experiment demonstrates the strong influence that the coastline topography has in affecting the flow over the SBC. The most significant variability in the SBC wind stress is evident when high pressure is centered off the California coast so that a northerly geostrophic flow is along the coastline. As this flow passes Pt. Conception, it creates a horizontal shear zone in the surface wind stress that can be reasonably simulated using the ARPS model. What is not yet clear is how the SBC flow adjusts as the large scale flow direction is altered by synoptic variability. Future modeling experiments will focus on this issue.

TRANSITIONS

Output from the model is being modified for use by the ocean modeling efforts and should be available in late 1998. Because the model uses a map projection and 2 levels of nesting, wind stress values must be interpolated from the ARPS grid to a uniform lat-lon grid. When finished, a file containing the gridded wind stress values for every hour will be transferred to the ONR ftp site.

RELATED PROJECTS

Much of the expertise developed in using the ARPS model will be applied to the National Ocean Partnership Program project on predicting the coastal circulation off of Oregon. Collaboration is also planned with L. Mahrt in testing improved surface boundary layer parameterizations for the coastal zone.

REFERENCES

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